PATENT ABSTRACTS OF JAPAN

(11)Publication number : 10-281832
(43)Date of publication of application : 23.10.1998

(51)Int.Cl. G01F 1/66

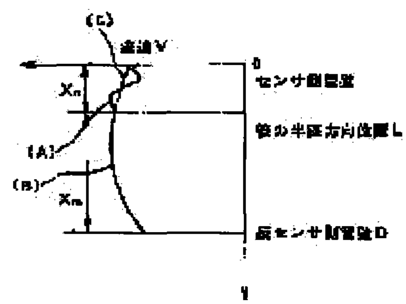
(21)Application number : 09-089088
(22)Date of filing : 08.04.1997

(71)Applicant : HITACHI LTD
(72)Inventor : ANZAI YOSHIRO
YAZAWA SETSUO
OKAMURA TOMOYOSHI
KOGA MASAAKI

(54) PULSE DOPPLER TYPE ULTRASONIC FLOWMETER

(57)Abstract:
PROBLEM TO BE SOLVED: To enhance accuracy in the measurement of flow rate by neglecting a current A in the vicinity of the pipe wall on the receiver side where the measurement accuracy is low and determining a current distribution data C in the vicinity of the pipe wall from a current distribution data B detected with high accuracy from a part other than the vicinity of the pipe wall and then calculating the flow rate from the current distribution data B and C.

SOLUTION: In the region Xm remote from the pipe wall, effect of noise reflected on a boundary face is suppressed and a normal current distribution B is detected. A current distribution indicator/corrector sets a normally detected current distribution B positive and extrapolates the positive current distribution B on the region Xm side thus determining a current distribution C by numeric analysis. The current distribution is approximated by a quadratic or cubic curve by a method of least squares, for example, and the current in the region Xm is extrapolated using that curve to obtain a current distribution as shown by a dashed line C. A flow rate calculator calculates the flow rate from the corrected current distributions b and C according to a specified formula.



LEGAL STATUS

[Date of request for examination]

[Date of sending the examiner's decision of rejection]

[Kind of final disposal of application other than the examiner's decision of rejection or application converted registration]

[Date of final disposal for application]

[Patent number]

[Date of registration]

[Number of appeal against examiner's decision of rejection]

[Date of requesting appeal against examiner's decision of rejection]

[Date of extinction of right]

CLAIMS

[Claim(s)]
[Claim 1] When a flow rate is computed from the velocity distribution of the detected measurement passage cross section in a pulse-doppler type ultrasonic flowmeter, The detection rate-of-flow data near the passage wall of the side which installed the ultrasonic transducer (A) are disregarded. Transpose to the velocity-distribution data (C) which extrapolate and are obtained from the velocity-distribution data (B) detected except near the wall surface to the above-mentioned passage wall side, and it corrects to them. It is the pulse-doppler type ultrasonic flowmeter characterized by applying the above-mentioned correction velocity distribution near the transducer side-attachment-wall side, and for the other cross section constituting the velocity distribution of a passage cross section with the application of the velocity-distribution data (B) detected with the transducer, and computing a flow rate based on the velocity distribution.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] This invention relates to the pulse-doppler type ultrasonic flowmeter of the fluid machinery used for a water supply system, storm sewage wastewater, agricultural water, etc. with respect to hydrometry.
[0002]
[Description of the Prior Art] In this kind of the hydrometry approach, the thing of a publication is in JP,8-125633,A as a thing of a pulse-doppler type ultrasonic sensing method, for example conventionally. According to this method, as shown, for example in drawing 4 , one ultrasonic transducer 2 is attached in the outer wall 1 of pump discharge tubing, the supersonic wave 3 of the letter of a burst (some pulse waves) is sent from there, and the above-mentioned transducer 2 receives the supersonic waves 5a and 5b scattered about from the minute particles 4a and 4b in tubing etc. As for close, a carrier beam signal gets down from the doppler shift of passing speed Vbcostheta of the travelling direction of the supersonic wave of a minute particle, i.e., frequency deltaf based on the rate of flow, to the received wave, it asks for deltaf by frequency analysis, and the rate of flow V is detected from a degree type.
[0003]
[Equation 1]
V=Cdeltaf/2f0costheta -- (several 1)
It is the acoustic velocity of C:water, and f0 here. : The frequency of a transmitted supersonic wave, a deltaf:doppler-shift frequency, theta: It is the include angle of the travelling direction of a supersonic wave, and a tube wall to make. The detection location L is called for by the degree type.
[0004]
[Equation 2]
L=C-t-sintheta/2 -- (several 2)
It is t:gate time here. If the gate time of this signal picking ** is changed, the time amount to which a supersonic wave goes and comes back from a transducer can change, and can change the location to measure. Thus, when the measuring point in tubing changes gate time, the rate of flow of the location can be detected by the Doppler signal, namely, can measure the velocity distribution in tubing. A flow rate is obtained by integrating with the acquired velocity distribution to a tubing cross section. Since the flow rate based on a velocity distribution is obtained with one transducer, the flowmeter of the accuracy of measurement with it can be obtained. [it is user-friendly and high]
[0005]
[Problem(s) to be Solved by the Invention] However, the following technical problems exist in the above-mentioned conventional technique. An example as a result of the velocity distribution in tubing when a pulse-doppler type ultrasonic flowmeter detects piping with a circular cross section as shown in the drawing 5 left is shown in the drawing 5 right. As shown in this drawing, the disordered velocity distribution (A) may be detected in the field of Xn near [by the side of a transducer] the tube wall. This is because the supersonic wave which came out of ultrasonic

component 2a in the transducer 2 of a supersonic wave reflects by transducer end-face 2b (or external wall surface 1a of tubing), or internal-surface 1b of tubing, and serves as a big noise to the ultrasonic signal of the normal scattered about from the particle in tubing and a Doppler signal is not acquired correctly. Such effect is the end face of ultrasonic component 2a, and the distance L0 of passage wall inner surface 1b. It becomes a problem when it cannot ignore compared with the measurement distance L of passage.

[0006] For reducing this noise, it is the distance L0 of passage wall inner surface 1a from the end face of ultrasonic component 2a. It is necessary to make it small or to make the acoustic impedance (consistency x acoustic velocity) of construction material the same as the liquid in passage. However, it is very difficult to implement such a policy. Because, distance L0 For making it small, it is necessary to make the diameter of ultrasonic component 2a small. Since the reinforcement of a scattered wave is weak, it becomes impossible to receive a received wave and it becomes impossible however, to acquire the rate of flow in tubing, even if it becomes impossible for the output of a supersonic wave to become small and for a supersonic wave to penetrate the passage wall 1 made of steel and can penetrate, if a diameter is made small. On the other hand, making the acoustic impedance of construction material the same as the water of the fluid of the measuring object needs to make a hole in a tube wall, it needs to install the aperture made of resin, and needs to install an ultrasonic transducer there. Such a thing is very difficult when measuring the flow rate of the existing pump.

[0007]

[Means for Solving the Problem] In case a flow rate is computed by integrating with the detected velocity distribution, the rate-of-flow data near [by the side of a transducer with the bad accuracy of measurement] the tube wall (A) are not applied, but extrapolate and ask for the velocity-distribution data near the tube wall (C) from the velocity-distribution data (B) detected with sufficient precision other than near the ****, and compute a flow rate from the above-mentioned velocity-distribution data (B) and (C).

[0008]

[Embodiment of the Invention] Drawing 1 explains the 1st operation gestalt of this invention. The ultrasonic transducer (sensor) 2 is connected to installation and a transducer 2 in the pulse-doppler type ultrasonic current meter 6 of the conventional technique in the external wall surface of passage 1. The flow rate correction equipment 7 which consists of flow rate calculation machine 7b which finds the integral to this current meter 6 from a display and rectifier 7a of a velocity distribution, and a velocity distribution, and calculates a flow rate is connected.

[0009] In such hydrometry equipment, the curve of the continuous line shown in drawing 2 as a distribution map of the relation between radial [of passage] and the rate of flow, i.e., radial [of the shaft-orientations rate of flow], is obtained as an output of the pulse-doppler type ultrasonic current meter 6. That is, since the acoustic impedances of a transducer, the ingredient of a passage wall, and the liquid in passage differ, the rate-of-flow distribution curve (A) of the range of the field Xn near the transducer by-pass wall may present a distribution configuration which is different in the velocity-distribution emergency of normal by the noise reflected in each interface. However, the inclination which a actual velocity distribution does not show irregularity in a radial distance short in this way, and dwindles the rate of flow toward a passage core or ****** by development of a boundary layer is shown. Therefore, if a flow rate is computed using the velocity distribution of (A) which does not show flow actual in this way, a right flow rate will not be obtained.

[0010] On the other hand, in the field of Xm which is separated from a tube wall, since the effect of the above-mentioned noise becomes small, a normal velocity distribution (B) is detected. Then, with a velocity-distribution display and a rectifier, the velocity distribution (B) detected normally is just carried out, it extrapolates to Field Xn side, and a velocity distribution (C) is searched for in numerical analysis. Extrapolation approximates a velocity distribution (B) with 2 - the 3rd curve for example, by the minimum root squaring methods, and when the rate-of-flow data of Field Xn ask using the curve, it is performed. A broken line (C) shows the velocity distribution acquired by such extrapolation. Thus, a flow rate is computed by the degree type by

flow rate calculation machine 7b in the corrected velocity distribution (C) and (B).
[0011]
[Equation 3]

$$Q=\int_0^D (V(c)+V(b))B(r)dr \quad \cdots (数3)$$

[0012] The rate of flow corrected near the V(c):tube wall here, the rate of flow by which it was detected other than near the V(b):tube wall, the diameter of D:passage, B (r): They are the measurement distance L of passage, and the width of face of the direction of a right angle.
[0013] If the curve which turns into the rate-of-flow distribution curve (B) from (C) in drawing 2 has neither an obstruction nor rapid deflection nor a junction pipe into the passage near the upstream of a measurement part, the rate of flow near a passage core is max, and since a boundary layer progresses as it goes to a tube wall side, the rate of flow will usually be dwindled. Therefore, the corrected rate-of-flow distribution curve shows a convex configuration, when taking the depth distance of the measuring object along an axis of abscissa and taking the rate of flow along an axis of ordinate. Therefore, since the correction curve is not suitable, correction enables it to display assessment that it is an error on a flow rate calculation machine in the 2nd example, when an approximation curve does not serve as a convex configuration. If it does in this way, it can be possible to prevent unsuitable correction and the accuracy of measurement of equipment can be raised. The 3rd example is the approach of setting the range Xn which disregards a velocity distribution (A) in drawing 2 as the distance Xn defined experimentally or theoretically with the construction material die length Ls of the wedge-shaped filler between dispatch component side 2a of two in an ultrasonic transducer, and field 2b attached in the tube wall of a transducer, and the construction material and thickness Lp of a wall of passage as shown in drawing 3 , and correcting a velocity distribution. If it does in this way, since the velocity distribution by which the range of the distance Xn which did not need to examine the velocity distribution detected and acquired in monitor display each time, and set it up beforehand was detected will be corrected automatically, quick measurement is attained.
[0014] The 4th example is explained using drawing 1 and drawing 2 . (B) is displayed on the monitor display of the velocity-distribution display and rectifier of drawing 1 as the velocity distribution (A) shown in drawing 2 at the beginning. Next, in case a velocity distribution (A) is corrected, the range Xn where the right velocity distribution is not acquired by the noise is judged by viewing, and the range Xn which corrects is set up by the manual. If it does in this way, since the more exact correction range can be set up, hydrometry precision can be raised more. When the maximum rate of flow of a test section has shifted from the core of a duct cross section, or the part where the rate of flow is fixed exists widely and a velocity distribution does not serve as a convex configuration simply, the effectiveness of this example is size.
[0015] The 5th example is explained using drawing 2 . A velocity distribution as shows the monitor display of a velocity-distribution display and rectifier 7b of drawing 1 R> 1 to drawing 2 is displayed. In this example, the color of a distribution curve and the class (the continuous line and broken line) of line which corrected by the original distribution curve and extrapolation which were detected, and were displayed are changed and displayed, and it carries out as [recognize / the difference of the curve before and behind correction / clearly]. By doing in this way, the mistake actuation at the time of correction with a monitor is prevented, and it can contribute to the improvement in the accuracy of measurement of the whole.
[0016]
[Effect of the Invention] According to this invention, when measuring the flow rate of the passage of a minor diameter comparatively with a pulse-doppler type ultrasonic flowmeter, it is possible to compensate lowering of the rate-of-flow accuracy of measurement near the tube wall by the side of installation of the transducer which exists intrinsically, consequently hydrometry precision improves.

[Translation done.]

TECHNICAL FIELD

[Field of the Invention] This invention relates to the pulse-doppler type ultrasonic flowmeter of the fluid machinery used for a water supply system, storm sewage wastewater, agricultural water, etc. with respect to hydrometry.

[Translation done.]

PRIOR ART

[Description of the Prior Art] In this kind of the hydrometry approach, the thing of a publication is in JP,8-125633,A as a thing of a pulse-doppler type ultrasonic sensing method, for example conventionally. According to this method, as shown, for example in drawing 4 , one ultrasonic transducer 2 is attached in the outer wall 1 of pump discharge tubing, the supersonic wave 3 of the letter of a burst (some pulse waves) is sent from there, and the above-mentioned transducer 2 receives the supersonic waves 5a and 5b scattered about from the minute particles 4a and 4b in tubing etc. As for close, a carrier beam signal gets down from the doppler shift of passing speed Vbcostheta of the travelling direction of the supersonic wave of a minute particle, i.e., frequency deltaf based on the rate of flow, to the received wave, it asks for deltaf by frequency analysis, and the rate of flow V is detected from a degree type.
[0003]
[Equation 1]
V=Cdeltaf/2f0costheta -- (several 1)
It is the acoustic velocity of C:water, and f0 here. : The frequency of a transmitted supersonic wave, a deltaf:doppler-shift frequency, theta: It is the include angle of the travelling direction of a supersonic wave, and a tube wall to make. The detection location L is called for by the degree type.
[0004]
[Equation 2]
L=C-t-sintheta/2 -- (several 2)
It is t:gate time here. If the gate time of this signal picking ** is changed, the time amount to which a supersonic wave goes and comes back from a transducer can change, and can change the location to measure. Thus, when the measuring point in tubing changes gate time, the rate of flow of the location can be detected by the Doppler signal, namely, can measure the velocity distribution in tubing. A flow rate is obtained by integrating with the acquired velocity distribution to a tubing cross section. Since the flow rate based on a velocity distribution is obtained with one transducer, the flowmeter of the accuracy of measurement with it can be obtained. [it is user-friendly and high]

[Translation done.]

EFFECT OF THE INVENTION

[Effect of the Invention] According to this invention, when measuring the flow rate of the passage of a minor diameter comparatively with a pulse-doppler type ultrasonic flowmeter, it is possible to compensate lowering of the rate-of-flow accuracy of measurement near the tube wall by the side of installation of the transducer which exists intrinsically, consequently hydrometry precision improves.

[Translation done.]

* NOTICES *

TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention] However, the following technical problems exist in the above-mentioned conventional technique. An example as a result of the velocity distribution in tubing when a pulse-doppler type ultrasonic flowmeter detects piping with a circular cross section as shown in the drawing 5 left is shown in the drawing 5 right. As shown in this drawing, the disordered velocity distribution (A) may be detected in the field of Xn near [by the side of a transducer] the tube wall. This is because the supersonic wave which came out of ultrasonic component 2a in the transducer 2 of a supersonic wave reflects by transducer end-face 2b (or external wall surface 1a of tubing), or internal-surface 1b of tubing, and serves as a big noise to the ultrasonic signal of the normal scattered about from the particle in tubing and a Doppler signal is not acquired correctly. Such effect is the end face of ultrasonic component 2a, and the distance L0 of passage wall inner surface 1b. It becomes a problem when it cannot ignore compared with the measurement distance L of passage.
[0006] For reducing this noise, it is the distance L0 of passage wall inner surface 1a from the end face of ultrasonic component 2a. It is necessary to make it small or to make the acoustic impedance (consistency x acoustic velocity) of construction material the same as the liquid in passage. However, it is very difficult to implement such a policy. Because, distance L0 For making it small, it is necessary to make the diameter of ultrasonic component 2a small. Since the reinforcement of a scattered wave is weak, it becomes impossible to receive a received wave and it becomes impossible however, to acquire the rate of flow in tubing, even if it becomes impossible for the output of a supersonic wave to become small and for a supersonic wave to penetrate the passage wall 1 made of steel and can penetrate, if a diameter is made small. On the other hand, making the acoustic impedance of construction material the same as the water of the fluid of the measuring object needs to make a hole in a tube wall, it needs to install the aperture made of resin, and needs to install an ultrasonic transducer there. Such a thing is very difficult when measuring the flow rate of the existing pump.

[Translation done.]

* NOTICES *

JPO and NCIPI are not responsible for any damages caused by the use of this translation.

1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

MEANS

[Means for Solving the Problem] In case a flow rate is computed by integrating with the detected velocity distribution, the rate-of-flow data near [by the side of a transducer with the bad accuracy of measurement] the tube wall (A) are not applied, but extrapolate and ask for the velocity-distribution data near the tube wall (C) from the velocity-distribution data (B) detected with sufficient precision other than near the ****, and compute a flow rate from the above-mentioned velocity-distribution data (B) and (C).
[0008]
[Embodiment of the Invention] Drawing 1 explains the 1st operation gestalt of this invention. The ultrasonic transducer (sensor) 2 is connected to installation and a transducer 2 in the pulse-doppler type ultrasonic current meter 6 of the conventional technique in the external wall surface of passage 1. The flow rate correction equipment 7 which consists of flow rate calculation machine 7b which finds the integral to this current meter 6 from a display and rectifier 7a of a velocity distribution, and a velocity distribution, and calculates a flow rate is connected.
[0009] In such hydrometry equipment, the curve of the continuous line shown in drawing 2 as a distribution map of the relation between radial [of passage] and the rate of flow, i.e., radial [of the shaft-orientations rate of flow], is obtained as an output of the pulse-doppler type ultrasonic current meter 6. That is, since the acoustic impedances of a transducer, the ingredient of a passage wall, and the liquid in passage differ, the rate-of-flow distribution curve (A) of the range of the field Xn near the transducer by-pass wall may present a distribution configuration which is different in the velocity-distribution emergency of normal by the noise reflected in each interface. However, the inclination which a actual velocity distribution does not show irregularity in a radial distance short in this way, and dwindles the rate of flow toward a passage core or ****** by development of a boundary layer is shown. Therefore, if a flow rate is computed using the velocity distribution of (A) which does not show flow actual in this way, a right flow rate will not be obtained.
[0010] On the other hand, in the field of Xm which is separated from a tube wall, since the effect of the above-mentioned noise becomes small, a normal velocity distribution (B) is detected. Then, with a velocity-distribution display and a rectifier, the velocity distribution (B) detected normally is just carried out, it extrapolates to Field Xn side, and a velocity distribution (C) is searched for in numerical analysis. Extrapolation approximates a velocity distribution (B) with 2 - the 3rd curve for example, by the minimum root squaring methods, and when the rate-of-flow data of Field Xn ask using the curve, it is performed. A broken line (C) shows the velocity distribution acquired by such extrapolation. Thus, a flow rate is computed by the degree type by flow rate calculation machine 7b in the corrected velocity distribution (C) and (B).
[0011]
[Equation 3]

$$Q=\int_0^D (V(c)+V(b))B(r)\,dr \qquad \cdots (数3)$$

[0012] The rate of flow corrected near the V(c):tube wall here, the rate of flow by which it was detected other than near the V(b):tube wall, the diameter of D:passage, B (r): They are the

measurement distance L of passage, and the width of face of the direction of a right angle.
[0013] If the curve which turns into the rate-of-flow distribution curve (B) from (C) in drawing 2 has neither an obstruction nor rapid deflection nor a junction pipe into the passage near the upstream of a measurement part, the rate of flow near a passage core is max, and since a boundary layer progresses as it goes to a tube wall side, the rate of flow will usually be dwindled. Therefore, the corrected rate-of-flow distribution curve shows a convex configuration, when taking the depth distance of the measuring object along an axis of abscissa and taking the rate of flow along an axis of ordinate. Therefore, since the correction curve is not suitable, correction enables it to display assessment that it is an error on a flow rate calculation machine in the 2nd example, when an approximation curve does not serve as a convex configuration. If it does in this way, it can be possible to prevent unsuitable correction and the accuracy of measurement of equipment can be raised. The 3rd example is the approach of setting the range Xn which disregards a velocity distribution (A) in drawing 2 as the distance Xn defined experimentally or theoretically with the construction material die length Ls of the wedge-shaped filler between dispatch component side 2a of two in an ultrasonic transducer, and field 2b attached in the tube wall of a transducer, and the construction material and thickness Lp of a wall of passage as shown in drawing 3 , and correcting a velocity distribution. If it does in this way, since the velocity distribution by which the range of the distance Xn which did not need to examine the velocity distribution detected and acquired in monitor display each time, and set it up beforehand was detected will be corrected automatically, quick measurement is attained.
[0014] The 4th example is explained using drawing 1 and drawing 2 . (B) is displayed on the monitor display of the velocity-distribution display and rectifier of drawing 1 as the velocity distribution (A) shown in drawing 2 at the beginning. Next, in case a velocity distribution (A) is corrected, the range Xn where the right velocity distribution is not acquired by the noise is judged by viewing, and the range Xn which corrects is set up by the manual. If it does in this way, since the more exact correction range can be set up, hydrometry precision can be raised more. When the maximum rate of flow of a test section has shifted from the core of a duct cross section, or the part where the rate of flow is fixed exists widely and a velocity distribution does not serve as a convex configuration simply, the effectiveness of this example is size.
[0015] The 5th example is explained using drawing 2 . A velocity distribution as shows the monitor display of a velocity-distribution display and rectifier 7b of drawing 1 R> 1 to drawing 2 is displayed. In this example, the color of a distribution curve and the class (the continuous line and broken line) of line which corrected by the original distribution curve and extrapolation which were detected, and were displayed are changed and displayed, and it carries out as [recognize / the difference of the curve before and behind correction / clearly]. By doing in this way, the mistake actuation at the time of correction with a monitor is prevented, and it can contribute to the improvement in the accuracy of measurement of the whole.

[Translation done.]

DESCRIPTION OF DRAWINGS

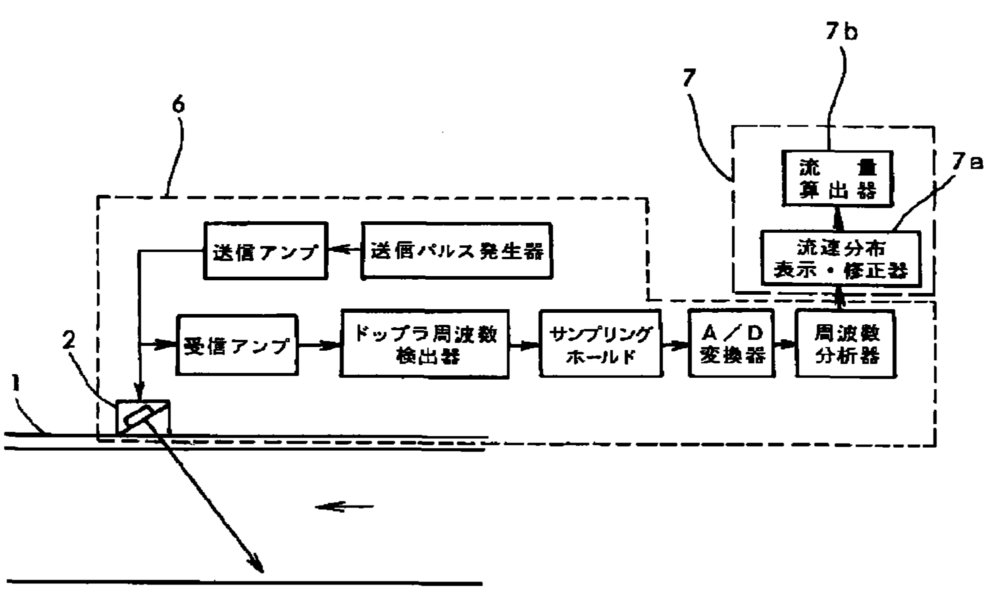
[Brief Description of the Drawings]
[Drawing 1] It is the block diagram showing the configuration of the example of this invention.
[Drawing 2] It is drawing showing the detected velocity distribution and its corrected velocity distribution.
[Drawing 3] It is the sectional view of the duct in which the transducer in which the 3rd example of this invention is shown was installed.
[Drawing 4] It is drawing explaining the principle of the pulse-doppler type ultrasonic flowmeter of the conventional technique.
[Drawing 5] It is drawing showing the mounting situation of the ultrasonic transducer for explaining the technical problem of the conventional technique, and the velocity distribution in detected tubing.
[Description of Notations]
1 [-- An underwater particle, 5 / -- The received wave, 6 based on a scattered wave / -- A pulse-doppler type ultrasonic current meter, 7 / -- Flow rate calculation equipment.] -- Measurement passage (tubing), 2 -- An ultrasonic transducer, 3 -- The letter supersonic-wave transmission wave of a burst, 4

[Translation done.]

DRAWINGS

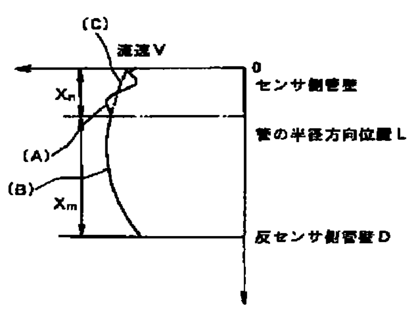
[Drawing 1]

図 1



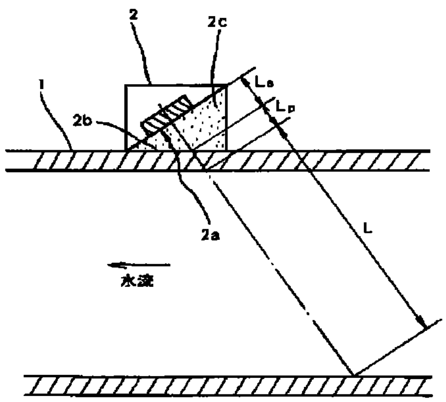
[Drawing 2]

図 2



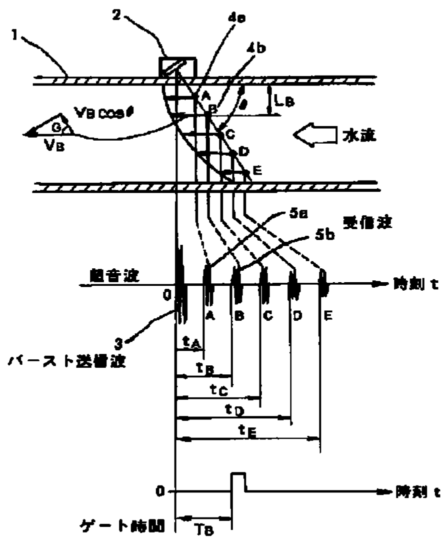
[Drawing 3]

図 3



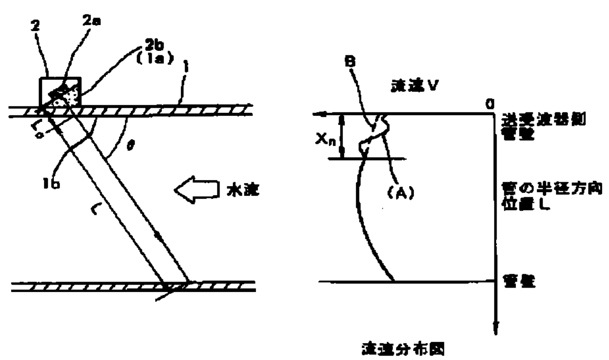
[Drawing 4]

図 4



[Drawing 5]

図 5



[Translation done.]

(19)日本国特許庁（ＪＰ）　(12) 公開特許公報（Ａ）　(11)特許出願公開番号

特開平10－281832

(43)公開日　平成10年(1998)10月23日

(51)Int.Cl.⁶	識別記号	F I	
Ｇ０１Ｆ　1/66	１０３	Ｇ０１Ｆ　1/66	１０３

審査請求　未請求　請求項の数１　ＯＬ　（全５頁）

(21)出願番号　特願平9－89088

(22)出願日　平成９年(1997)４月８日

(71)出願人　000005108
株式会社日立製作所
東京都千代田区神田駿河台四丁目６番地

(72)発明者　安斎　良郎
茨城県土浦市神立町603番地　株式会社日立製作所土浦工場内

(72)発明者　矢沢　節雄
茨城県土浦市神立町603番地　株式会社日立製作所土浦工場内

(72)発明者　岡村　共由
茨城県土浦市神立町603番地　株式会社日立製作所土浦工場内

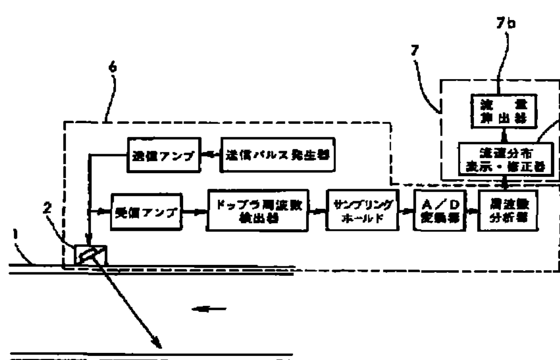
(74)代理人　弁理士　小川　勝男

最終頁に続く

(54)【発明の名称】　パルスドップラ式超音波流量計

(57)【要約】
【課題】パルスドップラ式超音波流量計において、超音波センサ設置壁近傍の流速測定精度が低下し、その結果、流量測定精度が低下するという問題を解決する。
【解決手段】測定精度の悪いセンサ近傍の流速測定結果は用いずに、精度よく測定される流路壁から離れた領域の測定結果から外挿してセンサ近傍の領域の流速を求め、その流速分布を用いて流量を求める。

図　1



【特許請求の範囲】

【請求項１】パルスドップラ式超音波流量計において、検出した測定流路断面の流速分布から流量を算出する際、超音波送受波器を設置した側の流路壁近傍の検出流速データ（Ａ）は無視し、壁面近傍以外で検出された流速分布データ（Ｂ）から上記流路壁側へ外挿して得られる流速分布データ（Ｃ）に置き換えて修正し、送受波器側壁面近傍は上記修正流速分布を適用し、それ以外の断面は送受波器で検出された流速分布データ（Ｂ）を適用して流路断面の流速分布を構成し、その流速分布に基づいて流量を算出することを特徴とするパルスドップラ式超音波流量計。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は、流量測定法に係わり、例えば、上水道・雨水排水・農業用水等のために用いられる流体機械のパルスドップラ式超音波流量計に関する。

【０００２】

【従来の技術】従来この種の流量測定方法において、パルスドップラ式超音波方式のものとしては、例えば、特開平8－125633 号公報に記載のものがある。本方式によれば、例えば図４に示すようにポンプ吐出管の外壁１に１個の超音波送受波器２を取り付け、そこからバースト状（幾つかのパルス波）の超音波３を発信し、管内の微小粒子４ａ，４ｂ等から散乱される超音波５ａ，５ｂ等を上記の送受波器２で受信する。その受信波には微小粒子の超音波の進行方向の移動速度$V_b \cos\theta$すなわち流速に基づく周波数Δｆのドップラシフトを受けた信号が入っており、周波数分析によりΔｆを求め、次式から流速Ｖが検出される。

【０００３】

【数１】

$$V = C\Delta f / 2 f_0 \cos\theta \quad \cdots（数1）$$

ここに、Ｃ：水の音速、f_0 ：送信超音波の周波数，Δｆ：ドップラシフト周波数，θ：超音波の進行方向と管壁とのなす角度である。検出位置Ｌは次式により求められる。

【０００４】

【数２】

$$L = C \cdot t \cdot \sin\theta / 2 \quad \cdots（数2）$$

ここに、ｔ：ゲート時間である。この信号取り込のゲート時間を変化させると、超音波が送受波器から往復する時間が変わり、測定する位置を変えることができる。このように、管内の測定位置はゲート時間を変えることにより、その位置の流速はドップラ信号で検出することが可能で、すなわち、管内の流速分布を測定できることになる。得られた流速分布を管断面に対して積分することにより流量が得られる。１個の送受波器で流速分布に基づく流量が得られるので、使い勝手がよく且つ高い測定精度の流量計を得ることができる。

【０００５】

【発明が解決しようとする課題】しかしながら、上記従来技術には以下の課題が存在する。図５左に示すような断面が円形の配管についてパルスドップラ式超音波流量計で検出した場合の管内の流速分布の結果の一例を図５右に示す。この図に示されるように送受波器側の管壁近傍のＸｎの領域には、乱れた流速分布（Ａ）が検出される場合がある。これは、超音波の送受波器２内の超音波素子２ａから出た超音波が、送受波器端面２ｂ（あるいは管の外壁面１ａ）や管の内壁面１ｂで反射し、管内の粒子から散乱された正規の超音波信号に対して大きなノイズとなり、ドップラ信号が正しく得られないからである。このような影響は、超音波素子２ａの端面と流路壁内面１ｂの距離L_0 が流路の測定距離Ｌに比べ無視できない場合に問題となる。

【０００６】このノイズを低減するには超音波素子２ａの端面から流路壁内面１ａの距離L_0 を小さくしたり、材質の音響インピーダンス（密度×音速）を流路内の液体と同じにする必要がある。しかし、このような方策を実施することは極めて困難である。というのは、距離L_0 を小さくするには超音波素子２ａの直径を小さくする必要がある。しかし、直径を小さくすると超音波の出力が小さくなり鋼鉄製の流路壁１を超音波が透過できなくなり、あるいは透過できても散乱波の強度が弱いため受信波を受信できなくなり、管内の流速を得ることができなくなる。一方、材質の音響インピーダンスを測定対象の流体の水と同じにすることは、管壁に穴をあけて樹脂製の窓を設置してそこに超音波送受波器を設置する必要がある。このようなことは既存のポンプの流量を測定する場合は、極めて困難である。

【０００７】

【課題を解決するための手段】検出された流速分布を積分して流量を算出する際、測定精度が悪い送受波器側の管壁近傍の流速データ（Ａ）は適用せず、管壁近傍以外の精度よく検出された流速分布データ（Ｂ）から管壁近傍の流速分布データ（Ｃ）を外挿して求め、上記の流速分布データ（Ｂ）と（Ｃ）から流量を算出する。

【０００８】

【発明の実施の形態】本発明の第１の実施形態を図１により説明する。流路１の外壁面に超音波送受波器（センサ）２を取り付け、送受波器２には従来技術のパルスドップラ式超音波流速計６が接続されている。本流速計６には流速分布の表示・修正器７ａ及び流速分布から積分して流量を求める流量算出器７ｂからなる流量修正装置７が接続されている。

【０００９】このような流量測定装置において、パルス

ドップラ式超音波流速計６の出力として、流路の半径方向と流速との関係すなわち軸方向流速の半径方向の分布図として図２に示す実線の曲線が得られる。すなわち、送受波器側管壁近傍の領域Ｘｎの範囲の流速分布曲線（Ａ）は、送受波器と流路壁の材料と流路内の液の音響インピーダンスが異なるため、それぞれの境界面で反射するノイズにより、正規の流速分布非常に異なった分布形状を呈する場合がある。しかし、実際の流速分布はこのように短い半径方向距離で凹凸を示すことはなく、境界層の発達により流路中心から管壁に向かって流速は漸減する傾向を示す。従って、このように実際の流れを示していない（Ａ）の流速分布を用いて流量を算出すると、正しい流量が得られない。

【００１０】一方、管壁から離れたＸｍの領域では上記のノイズの影響が小さくなるので正常な流速分布（Ｂ）が検出される。そこで、流速分布表示・修正器により、正常に検出された流速分布（Ｂ）を正にして領域Ｘｎ側に外挿して流速分布（Ｃ）を数値解析的に求める。外挿は、流速分布（Ｂ）を例えば最少二乗法で２～３次曲線で近似し、その曲線を用いて領域Ｘｎの流速データが求めることにより行われる。このような外挿により得られた流速分布を破線（Ｃ）で示す。このようにして修正された流速分布（Ｃ）及び（Ｂ）を流量算出器７ｂで次式により流量が算出される。

【００１１】

【数３】

$$Q=\int_0^D (V(c)+V(b))B(r)\,dr \quad \cdots (\text{数}3)$$

【００１２】ここに、Ｖ（ｃ）：管壁近傍の修正した流速，Ｖ（ｂ）：管壁近傍以外の検出された流速，Ｄ：流路の直径，Ｂ（ｒ）：流路の測定距離Ｌと直角方向の幅である。

【００１３】図２において流速分布曲線（Ｂ）と（Ｃ）からなる曲線は、測定箇所の上流近傍の流路内に障害物や急激な曲がりや合流管がなければ、通常、流路中心付近の流速が最大で、管壁側に向かうに従い境界層が発達するため流速は漸減する。従って、修正した流速分布曲線は、横軸に測定対象の流路幅距離をとり縦軸には流速をとるとき、上に凸な形状を示す。従って、第２の実施例では、近似曲線が上に凸な形状とならない場合は、修正曲線が適切でないので修正は誤りであるとの評価を流量算出器に表示できるようにするものである。このようにすれば、不適切な修正を防止することが可能で、装置の測定精度を向上させることができる。第３の実施例は、図２において流速分布（Ａ）を無視する範囲Ｘｎを、図３に示すように超音波送受波器内２の発信素子面２ａと送受波器の管壁に取り付ける面２ｂとの間の楔状の充填材の材質長さＬｓ及び流路の壁の材質と厚さＬｐにより実験的あるいは理論的に定められる距離Ｘｎに設定して流速分布を修正する方法である。このようにすれば、検出して得られた流速分布をモニタ画面にてその都度検討する必要はなく、あらかじめ設定した距離Ｘｎの範囲の検出された流速分布を自動的に修正するので、迅速な測定が可能となる。

【００１４】第４の実施例を図１と図２を使って説明する。図１の流速分布表示・修正器のモニタ画面には図２に示す流速分布（Ａ）と（Ｂ）が当初表示される。次に流速分布（Ａ）の修正を施す際、ノイズにより正しい流速分布が得られていない範囲Ｘｎを目視により判断し、修正を施す範囲Ｘｎをマニュアルにて設定するようにしたものである。このようにすれば、より的確な修正範囲を設定できるので、流量測定精度をより向上させることができる。測定部の最大流速が管路断面の中心からずれていたり、流速が一定の箇所が広く存在する場合等、流速分布が単純に上に凸な形状とならないような場合に、本実施例の効果が大である。

【００１５】第５の実施例を図２を使って説明する。図１の流速分布表示・修正器７ｂのモニタ画面は図２に示すような流速分布が表示される。本実施例では検出された本来の分布曲線と外挿により修正して表示された分布曲線の色や線の種類（実線や破線）を変えて表示し、修正前後の曲線の相違を明瞭に認識できるようしたものである。このようにすることにより、モニタでの修正作業時のミス操作を防ぎ全体の測定精度向上に寄与できる。

【００１６】

【発明の効果】本発明によれば、パルスドップラ式超音波流量計で比較的小径の流路の流量を測定するとき、本質的に存在する送受波器の設置側の管壁付近の流速測定精度の低下を補うことが可能で、その結果、流量測定精度が向上する。

【図面の簡単な説明】

【図１】本発明の実施例の構成を示すブロック図である。

【図２】検出された流速分布とその修正した速度分布を示す図である。

【図３】本発明の第３の実施例を示す送受波器を設置した管路の断面図である。

【図４】従来技術のパルスドップラ式超音波流量計の原理を説明する図である。

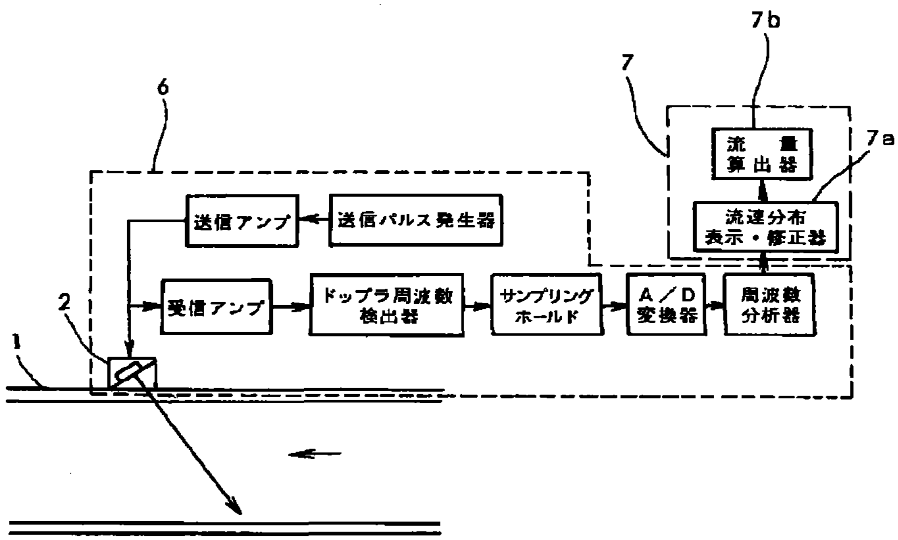
【図５】従来技術の課題を説明するための超音波送受波器の取付状況と検出された管内の流速分布を示す図である。

【符号の説明】

１…測定流路（管）、２…超音波送受波器、３…バースト状超音波送信波、４…水中の粒子、５…散乱波に基づく受信波、６…パルスドップラ式超音波流速計、７…流量算出装置。

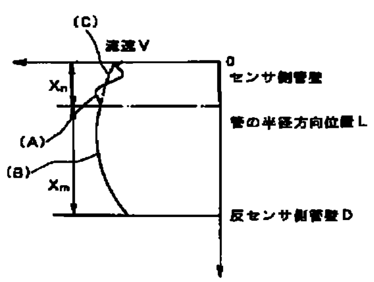
【図１】

図 1



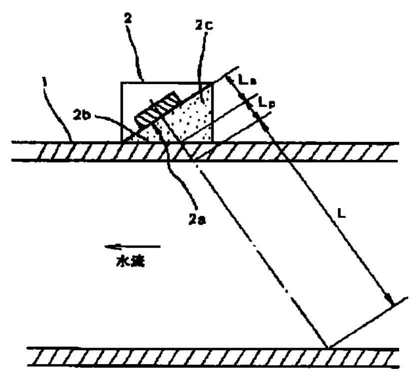
【図２】

図 2



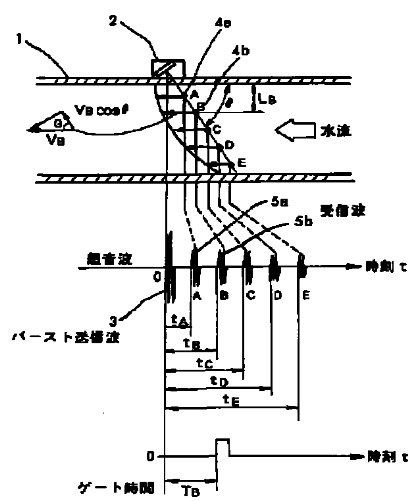
【図３】

図 3



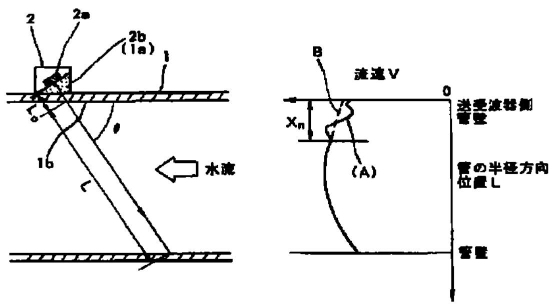
【図４】

図 4



【図５】

図　5



フロントページの続き

(72)発明者　古閑　誠明
茨城県土浦市神立町603番地　株式会社日立製作所土浦工場内